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Feeding practice and influence on selected blood parameters in show jumping horses competing in Switzerland

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Abstract: The aim of this study was to compare the nutritional management of show jumping horses in practice with recommendations from the literature. Additionally, the effects of these feeding practices on several blood metabolic parameters before and after exercise were studied. Blood samples were collected in the field from 27 different horses at 71 trials on the level M1 to S2 show jumping competitions in Switzerland and questionnaires on feeding practice of the studied horses were evaluated. The questionnaires revealed that during training and on tournament days horses received on average 3.1 kg of concentrate per day (min. 2.0 kg, max. 6.6 kg) divided into two to three meals. The horses were fed on average 6.9 kg of roughage per day (min. 4.0 kg, max. 13.0 kg). Additionally, it was observed that the horses received the last meal on average 6 h 10 min (min. 1 h 50 min, max. 12 h 30 min) before the start of the first show jumping turn, respectively, 7 h 30 min (min 1 h 50 min, max. 13 h 0 min) before the second turn. Seven horses (35%) had access to hay waiting in the trailer between two turns. The statistical analysis revealed no significant influence of the concentrate feeding time point on lactate, triglyceride and insulin levels, but a significant influence on free fatty acids (FFA) and blood glucose concentrations. Roughage feeding of the show jumping horses 2-4 h prior to exercise revealed the most remarkable changes in blood parameters during the show jumping course. These results received under field conditions should be approved in future under standardized conditions.

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Running title: Feeding and blood parameters in show jumping horses

Feeding practice and influence on selected blood parameters in show jumping horses competing in Switzerland

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Summary

The aim of the present study was to compare the nutritional management of show jumping horses in practice with recommendations from the literature. Additionally, the effects of these feeding practices on several blood metabolic parameters before and after exercise were studied. Blood samples were collected in the field from 27 different horses at 71 trials on the level M1 to S2 show jumping competitions in Switzerland and questionnaires on feeding practice of the studied horses were evaluated. The questionnaires revealed that during training and on tournament days horses received on average 3.1 kg of concentrate per day (min. 2.0 kg, max. 6.6 kg) divided into two to three meals. The horses were fed on average 6.9 kg of roughage per day (min. 4.0 kg, max. 13.0 kg). Additionally, it was observed, that the horses received the last meal on average 6 h 10 min (min. 1 h 50 min, max. 12 h 30 min) before the start of the first show jumping turn respectively 7 h 30 min (min 1 h 50 min, max. 13 h 0 min) before the second turn. Seven horses (35%) had access to hay waiting in the trailer between two turns. The statistical analysis revealed no significant influence of the concentrate feeding time point on lactate, triglyceride and insulin levels, but a significant influence on free fatty acids (FFA) and blood glucose concentrations. Roughage feeding of the show jumping horses 2 to 4 hours prior to exercise revealed the most remarkable changes in blood parameters during the show jumping course. These results received under field conditions should be approved in future under standardized conditions.

Keywords: performance, blood glucose, lactate, free fatty acids, triglyceride, insulin

Introduction

Nutritional management, including the composition of the ration, feeding schedule and feeding technique, plays an important role in energy supply and the performance of the equine athletes. Energy imbalances in athletic humans (Steinacker et al., 2005), as well as in athletic horses (Leleu and Haentjens, 2010) have been related to chronic fatigue and other features of the overtraining syndrome. During intermittent sprint, like in show jumping competitions, there is a higher demand for rapidly available ATP than during exercise with a constant average speed (Kingston, 2004). For this reason, it is generally assumed in the literature for horses, that short, intensive work is better supported by a starch- or glucose-rich diet, while for long persistent work at medium intensity a high-fiber and high-fat diet is more useful (Ellis and Hill, 2005). Pagan and Harris (1999) recommended that no grain should be fed before any type of exercise, but a small quantity of hay should be provided They showed that time of grain feeding affected glycaemic response, plasma protein level and water intake post feeding. Feeding grain reduced free fatty acid (FFA) availability and increased blood glucose disappearance during exercise. Feeding only forage before exercise did not adversely affect performance (Pagan and Harris, 1999). The highest blood glucose concentration is usually achieved between 90 to 120 minutes after starch intake (Williams et al., 2001; Bothe, 2001). The peak value for insulin is recorded at about 90–240 min after grain feeding (Stull and Rodiek, 1995; Jose-Cunilleras et al., 2002; Vervuert et al., 2008). The post-prandial insulin peak restrains fat oxidation and promotes storing of glucose and a transient hypoglycemia occurs (Lawrence et al., 1995; Stull und Rodiek, 1995; Vervuert et al., 2007). The release of FFA in the circulation is delayed and the horse has to use more of the storage glycogen as an energy source. For this reason exhaustion occurs earlier if exercise is demanded short time after concentrate feeding (Harris and Harris, 2005). This mechanism is only active at the onset of work, because the effect of insulin is suppressed by prolonged or repeated work (Harris and Harris, 2005). Horses that received a roughage-rich diet showed a greater capacity for gluconeogenesis compared to horses fed a starch-rich diet. For this reason, the normal blood glucose levels can be maintained for a longer period consuming a diet rich in roughage

(Frape, 1998). This is due to the fact that up to 60% of equine blood sugar is produced in the liver via gluconeogenesis from propionate (Simmons and Ford, 1991). However, some authors recommend restrictive roughage feeding, starting 3 days before intense exercise of short duration, because it causes less water uptake and storage in the intestine and therefore reduces the body weight and energy expenditure during running (Rice et al., 2001). In eventing horses neither a beneficial nor a detrimental effect from feeding large amounts of roughage could be shown, because the majority of horses were fed with roughage ad libitum (Brunner et al., 2012). The provision of glucose from body reserves, glycogenolysis and gluconeogenesis as well as the use of free fatty acids as an energy source increase blood glucose concentrations in prolonged (Reynolds et al., 1993; Stull and Rodiek, 1995; Lawrence et al., 1995; Trilk et al., 2002; Kavazis et al., 2004) or strenuous (Freestone et al., 1992; Heppes, 2003) exercise leading to hyperglycemia. Lekeux et al. (1991) studied the consequence of a show jumping competition on blood glucose levels. The blood glucose resting values (5.47 ± 0.15 mmol/l) decreased significantly during exercise (post exercise values: 4.84 ± 0.21 mmol/l) (Lekeux et al., 1991). Regarding the lipid metabolism, the fatty acid concentration in blood is low at the beginning of exercise and then FFA levels increase if exercise persists, due to the slow onset of lipid mobilization (Pagan et al., 1995; Zierler, 1999). Eventing horses exhibited increased blood free fatty acid concentrations in all three disciplines as well as increased triglyceride values during cross-country and show jumping competition (Brunner et al., 2012). In a study with trotters (Pösö et al., 1989), the increase of plasma triglyceride concentrations was correlated to the intensity of the trot.

The objective of this field study was to compare the practical feeding of show jumping horses with recommendations in the literature and to study the influence of feeding time and quantity on blood metabolic parameters to provide new insights into the feeding practice and its effects on show jumping horses.

Material and methods

In the present study 20 different horses and their feeding regimen were investigated. The horses had in total 71 accounted tournament starts. Data on feeding and training of the horses were recorded with the help of a questionnaire. The questions on the feeding during training and in tournament days included: concentrate and roughage quantity and type as well as feeding time, in relation to exercise, feeding sequence and frequency per day, intensity and duration of training, adaptation of feeding to exercise levels, feeding of oil, salt and electrolytes, grazing time and duration, duration of transport to the tournament, the weight of the horse, and a detailed listing of the exact diet fed per meal and feeding times over the competition. The feeding regime was not changed due to the study design. The energy content of the roughage was estimated using average values of normal Swiss hay. As energy content of the concentrate the mean value of all the different mixed feeds given by the manufacturer was used. The results on these parameters are listed in the result section. Blood samples were collected on four tournaments from 27 different horses with 71 competition starts in M1 to S2 show jumping competitions. Samples were taken 20–40 min before exercise, i.e., after the last feeding but before the warm-up, and within 3 min after the end of the parcours. All four competitions were held in Switzerland. The horses evaluated, included nine warm-blood mares, six warm-blood stallions and twelve warm-blood geldings. They were on average 9.5 years old (min. 6, max. 13 years old) and weighed 598 kg (min. 550 kg, max. 650 kg). The horses had mainly body condition scores of 4 to 5 out of 9 using the chart provided in Schramme (2003). Blood samples were collected using EDTA Vacutainer ® (BD Vacutainer, Allschwil, Switzerland). Blood glucose and blood lactate were measured immediately after drawing the samples using a rapid test kit (Glucose: Bayer, Zurich, Switzerland, blood lactate: Arkray, Tokyo, Japan). The blood samples additionally were centrifugated for 10 minutes using 10,000 turns per minute. Plasma was frozen and stored at -80°C until analyses were performed. Insulin was measured with an ELISA (Mercodia Equine Insulin ELISA, Mercodia AB, Uppsala, Sweden), triglycerides, and free fatty acids were measured using an autoanalyzer (COBAS MIRA Chemistry Analyzer, Roche, Basel, Switzerland) with commercially available tests (triglycerides: enzymatic colorimetric test (DIA 00660), Diatools, Roche, Basel, Switzerland; free fatty acids: (Wako HR-series NEFA-HR (2), Wako Pure Chemical Industries Ltd., Osaka, Japan).

The classification of the horses into groups for comparison of parameters is explained in table 1. The study protocol is approved by the Animal Welfare and Ethics Committee of Switzerland.

Statistical analyses:

Blood parameters were taken before and after each turnaround at the tournaments. Multivariate analysis of variance for repeated measures (MANOVA) was performed with the group as a cofactor included in the model to test differences of the time-dependent patterns between groups. The factor of exercise was included in the model. The test within subjects indicated whether significant changes occurred during the whole period for all animals. The factor exercise level tested whether the changes differed between the different exercise levels within the groups. The trend analysis was a breakdown of the tests within subjects, which gave an indication of the form of the changes over time. To avoid false conclusions because of a violation of the assumption of compound symmetry, a Huynh–Feldt correction was performed. Furthermore, the difference between groups at specific times was tested with the Mann–Whitney U-test (nonparametric) to limit the influence of extreme values. The level of significance was set at $p \leq 0.05$ for all tests. All statistical analyses were performed using SYSTAT version 11.0 (SPSS, Chicago, IL, USA). If several tests were performed for one parameter, a Bonferroni adjustment of the significance level (p divided by the number of tests) was performed. All data were described in the text as median with maximum and minimum values.

Results

The results regarding feeding quantity, feeding time point (concentrate and roughage) and energy provision during training period as well as on competition days are summarized in tab. 2. During the training period the horses were fed 3.1 kg concentrate per day (min. 2.1 kg, max. 5.6 kg) and on tournament days 3.1 kg per day (min. 2.0 kg, max. 6.6 kg) divided into 2 to 3 meals. As the last meal before the first turn 1.4 kg concentrate (min. 0.8 kg, max. 2.6 kg) were fed and before the second turn 0.1 kg (min. 0.0 kg, max. 1.2 kg). The horses received their last meal on average 6 h 12 min (min. 1 h 50 min, max. 12 h 30 min) before starting the first show jumping course or 7 h 31 min (min. 1 h 50 min, max. 13 h 0 min) before the second turn, respectively. Three of the 20 horses with full feeding history were fed with grass silage (15%). The remaining 17 horses were fed hay. No horse had free access to roughage. Seven horses (35%) had access to hay while waiting in the trailer for the next turn. The horses had access to roughage until 5 h 04 min (min. 1 h 0 min, max. 12 h 30 min) before the first show jumping turn and until 5 h 46 min (min. 1 h 0 min, max. 13 h 0min) before the second turn. Horses receiving hay in the trailer, had access to hay up to 1 h before the second turn when they were prepared for the next turn.

Median blood glucose concentrations decreased significantly during show jumping courses ($p< 0.00001$), only in seven turns out of 71 (9.9%) the horses showed a slight rise of the blood glucose concentration (tab. 3). No horse was hypoglycaemic (defined as blood glucose value ≤ 3 mmol/l) before exercise, compared to eleven hypoglycaemic post exercise values out of 57 turns (19.2 %), with blood glucose values going down to 1.9 mmol/l. During the show jumping course highly significant ($p \leq 0.0001$) decreases in plasma insulin concentrations were observed (tab. 3). Only two horses were above the upper insulin resting range (0.93 µg/l; Frank et al., 2009) at the moment of tournament start. The rises in blood lactate concentrations after the course were highly significant ($p \leq 0.0001$). As shown in tab. 3, after the show jumping course, the horses reached median lactate concentrations of 4.3 mmol/l (min. 0.6 mmol/l, max. 8.1 mmol/l). During show jumping, the horses showed significantly increased triglyceride values ($p < 0.0001$) and a significant increase ($p = 0.008$) of FFA in the blood (tab. 3).

The statistical analysis revealed no significant influence of the concentrate feeding time point on blood glucose, lactate, triglyceride or insulin levels (data not shown). The group C2-6h showed slightly decreasing FFA values during exercise. This is significantly ($p = 0.047$) different to the other groups as in these the FFA values increased during exercise (tab. 4).

The roughage feeding group R2-6h had significantly higher blood glucose resting values compared with group R<2h and group R>6h ($p = 0.033$) (fig. 1). Additionally there was a tendency towards higher glucose stress values after exercise in group R2-6h ($p = 0.076$). The group R2-6h had also significantly higher blood FFA resting values, with a decrease during exercise, compared to the other two groups, which had low blood FFA resting values with an increase during load ($p= 0.011$) (tab. 4). There was no obvious influence of the roughage feeding time on blood concentrations of insulin, triglycerides or lactate (mean values of all horses shown in tab. 3).

Comparing the three groups with the different show jumping course length, the group 500-580 m had a tendency ($p = 0.092$) to a lesser decrease in blood glucose (median 0.2 mmol/l), compared to the other two groups (fig. 2) and also compared to the median from all trials (median 0.7 mmol/l). The ridden speed had a significant influence on the decrease in blood glucose concentration ($p = 0.005$). The higher the speed, the higher was the post exercise stress blood glucose value and vice versa (tab. 5). The speed had a significant influence on blood lactate accumulation ($p = 0.0027$) (tab. 5).

Discussion

The feeding schedule and ration composition has substantial influences on the health and digestion of athletic horses and therefore should be carefully considered in management evaluations of these animals (McKenzie, 2011). The show jumping horses in this study were fed significantly less concentrate than racehorses (6.16 to 8.15 kg day^{-1}; Glade, 1983; Frape 1998) and eventing horses (4.0 kg day^{-1}; Brunner et al., 2012), but they received significantly more than endurance horses (2.27 kg day^{-1}; Coenen, 2002). Starch intake should be limited to <1 g/kg BW per meal (Luthersson et al., 2009), so as to prevent health issues like equine gastric ulcer syndrome (EGUS) or starch overload, i.e., approximately 1.0 kg concentrate $meal^{-1}$ $horse^{-1}$. Meyer et al. (2014) instead recommend an upper limit of 0.3 kg grain per 100 kg BW per meal. This recent recommendations were obeyed by a few of the feeding regimes evaluated in this study. The highly significant decrease in blood glucose during show jumping supports the findings by Lekeux et al. (1991) and could be explained by the short duration of the work-load and the blood samples taken immediately after exercise, so that there was not enough time for a hyperglycemia to occur. The tendency towards a lower decrease in blood glucose during exercise in group 500-580 m seems to be induced by a mobilization of glucose and could be the first step toward an upcoming hyperglycemia described in literature in prolonged (Reynolds et al., 1993; Stull and Rodiek, 1995; Lawrence et al., 1995; Trilk et al., 2002; Kavazis et al., 2004) and strenuous (Freestone et al., 1992; Heppes, 2003) exercise. A higher speed enhanced the stress blood glucose value compared to a slower speed. During the show jumping courses, the plasma insulin concentrations decreased (tab. 3). In contrast it was shown with hyperglycaemic clamp techniques that moderate intensity exercise in horses enhances the ability of physiological hyperinsulinaemia to stimulate whole body glucose uptake (Geor et al., 2010; Kemmink et al., 2010). The anaerobic threshold of lactate, located between 1.3 and 4 mmol/l (Sexton et al., 1987; Lindner, 2010), was achieved or exceeded in more than 97 % of the trials. The increase of the blood lactate values after a show jumping course in the horses of the present study is comparable to the post exercise lactate values detected in show jumping horses by other authors (Lekeux et al., 1991; Schöneseiffen, 2000). A study performed at the same time by the authors in eventing horses (Brunner et al., 2012) resulted in a much lower lactate accumulation after the show jumping course (1.6, min. 0.6, max. 4.6) compared with the show jumping specialists even though the course levels were comparable. Maybe the eventing horses were fitter and had a higher anaerobic threshold than the show jumping horses. Another possibility would be that, the different type of horse breeds (heavier horses for show jumping) or the different speed had an influence on lactate accumulation. Roberts et al. (2014) demonstrated that horses with higher blood lactate values after jumping showed decreased show jumping performance and were more likely to display muscle soreness. Therefore it is advisable to minimize elevation in blood lactate during competing through adequate training programs as well as through an accordant feeding regime, (as example not using roughage of bad quality, adding fat to the feed or utilizing buffering strategies (Ellis and Hill, 2005; Cornic, 2002; Oldriutenborgh-Oosterbaan et al., 2002; Frape, 1998)).

The constant to slightly decreasing triglyceride values in group 300-400 m compared to the rising triglyceride values in the other two groups, seem to confirm the findings in literature, suggesting that only strenuous exercise leads to a rise in blood triglyceride values (Pösö et al., 1989).

The influence from concentrate feeding time point versus roughage feeding time point is difficult to separate from each other because the horses were often classified into the same concentrate and roughage group. Regarding the concentrate feeding time point prior to exercise the only significant influence was on the blood FFA values. The lowering effect from a high starch diet on FFA blood values described in the literature (Pagan and Harris, 1999; Zimmerman et al., 1991) was supported by the results of the current study. The roughage feeding time point influenced also the blood glucose values with significantly higher resting blood glucose values in group R2-6h and a tendency toward higher post exercise blood glucose values in the same group. Maybe the group R2-6h could use the FFAs as energy source and for this reason retain more blood glucose. The group R2-6h showed the highest pre exercise values of FAA with a slight decrease during exercise, compared to low resting values and an increase of the FFA blood concentration in the other groups (tab. 4).

Generally the last feeding time point before exercise was far away from competition start and maybe therefore did not influence the blood values as much as suspected, but if horses reached the playoff short time after the first turn, the final blood values tended to be hypoglycaemic. Unfortunately, the number of horses reaching the playoff turns was too low for a statistical evaluation of these data, but as an example the blood glucose values of a typical starch rich fed horse were 3.7 mmol/l before the competition start, 3.6 mmol/l after the first turn, but decreased to 2.6 mmol/l after the playoff turn. In a study presented by Stewart-Hunt and colleges (Stewart-Hunt et al., 2010), a high starch diet resulted in decreased insulin sensitivity that was compensated by an increase in muscle membrane glucose transporter content in untrained horses. The energy content of the roughage was estimated using average values of normal Swiss hay, since no proximate analysis or calorimetric measurements were performed. As energy content of the concentrate the mean value of all the different mixed feeds given by the manufacturer was used (tab. 2). Comparing the provided total daily energy with maintenance requirement respectively with the requirement for work load, the overall exercise intensity of the evaluated show jumping horses must be assumed as medium work load.

In conclusion, the findings in this study disagree with the general assumption that short intensive work is better supported by a starch-rich diet, but agrees widely with finding from Pagan and Harris (1999); the show jumping horses investigated seemed to profit most from roughage feeding two to six hours prior to exercise. Concentrate feeding did not show a great influence on blood parameters at all. These results received under field conditions should be approved in future under standardized conditions.

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Legends

Table 1: Classification of the horses into different groups regarding the show jumping course or there feeding regime.

Table 2: Feeding (concentrate and roughage) quantity, feeding time point and energy provision during training period as well as on competition days and before each turn

Table 3: Pre- and post exercise median, minimal and maximal values of blood glucose, blood insulin, blood lactate, triglyceride (TG) and free fatty acids (FFA) from 27 horses participating at 71 competition trials.

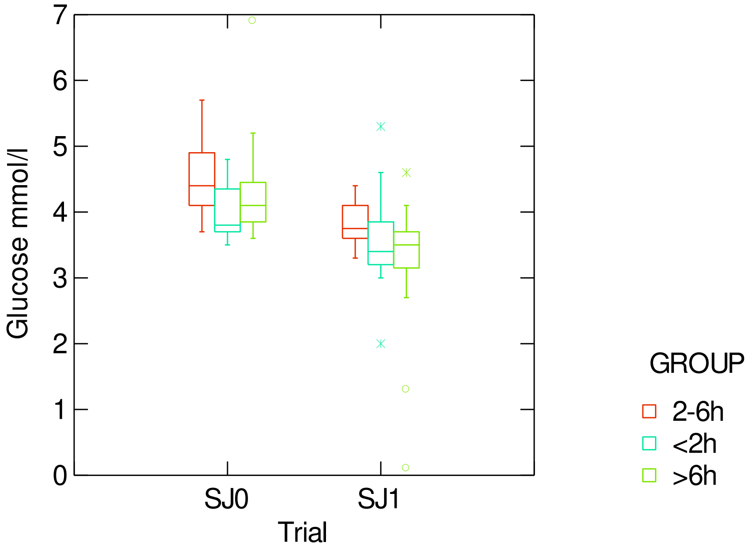
Table 4: Median, minimal and maximal free fatty acid (FFA) values compared with the last feeding time point before exercise in mmol/l.

Table 5: Blood glucose and blood lactate median, minimal and maximal values compared with the ridden speed during the show jumping course in mmol/l.

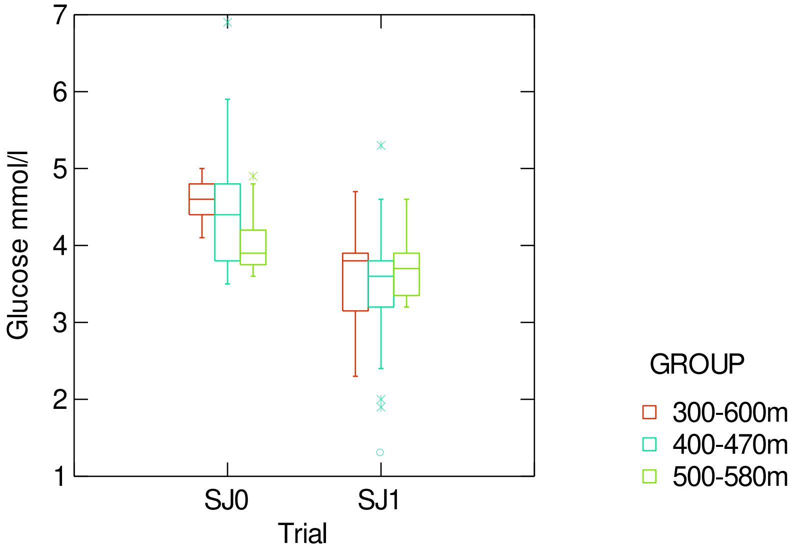
Figure 1: Box-plot representation of blood glucose concentrations for 71 trials, in mmol L^{-1} before (SJ0) and after (SJ1) the show-jumping course. The horses are divided into three groups regarding the last feeding time point of roughage. The length of each box shows the range of the central 50% of the values, with the box hinges at the first and third quartiles (25 and 75% of the values, respectively), and the line within the box showing the median value (50%). The whiskers show the range of values within the inner fences. Values between the

inner and the outer boundaries are plotted with asterisks (“outside values”), while values outside the outer boundaries are plotted as empty circles (“far outside values”).

Figure 2: Box-plot representation of blood glucose concentrations for 71 trials, in mmol L^{-1} before (SJ0) and after (SJ1) the show-jumping course. The trials are divided into three groups regarding the show jumping course length. The length of each box shows the range of the central 50% of the values, with the box hinges at the first and third quartiles (25 and 75% of the values, respectively), and the line within the box showing the median value (50%). The whiskers show the range of values within the inner fences. Values between the inner and the outer boundaries are plotted with asterisks (“outside values”), while values outside the outer boundaries are plotted as empty circles (“far outside values”).



7
6
5
4
3
2
1
0
Glucose mmol/l
SJ0
SJ1
Trial
GROUP
2-6h
<2h
>6h



Glucose mmol/l
7
6
5
4
3
2
1
SJ0
SJ1
Trial
GROUP
300-600m
400-470m
500-580m